Continuous measurements of eyeball area and their spectrum analyses -- Toward the quantification of rest rhythm of horses by image processing --

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Abstract-**The motion of eyelids and eyeballs in domestic animals had been recognized well agreement with the sleep depth estimated by spectrum analyses of electroencephalogram at half-closed eye and fully closed eye. This study aimed at quantitative estimating rest rhythm of horses by the analyses of eyeball movement. The mask attached with a miniature CCD camera was newly developed. The continuous images of the horse eye for about 24 hours were transmitted by telemetry system and were recorded to a time-lapse video recorder. The continuous images were captured hard disc (rate 1 frame / 2 sec), the time information was obtained by OCR technology, the eyeball area was smoothed to average gray values, and done threshold for segmentation. The eyeball area was obtained via image processing and analyzed the spectrum. The temporal trend, the histogram and the spectrum of eyeball area were calculated. As for the results, the fluctuating status of eyeball area was analyzed quantitatively, and the rest rhythm of horses was clearly observed. It is possible to apply this technology to other animals.**

Keywords **- Rest rhythm of horses, continuous measurements of eyeball, telemeter system, image processing**

I. INTRODUCTION

The rest behaviors, such as sleep, napping and awakening, of domestic animals have been observed generally by the watching of their behaviors. However, their rests are performed while they are lying down, on the contrary they are often sleeping while standing. As known widely that their rest behaviors are not tightly related with their appearance behaviors. The reason is that the herbivorous animals, horses themselves, are able to be active inherently at any time even they are sleeping. Namely, their lying situation means not directly to the rest, and their standing indicates not only the active condition. Also it was reported that the cattle ruminates when they show at half-closed and fully closed eyes.

The subjects of this study were thoroughbred horses, which have not been investigated comparing with other domestic animals, such as cattle, pigs and sheep.

The rest behaviors are controlled with the parasympathetic nervous system, and are showing directly their mental situations. Nemoto et al. had already measured and reported that the rest behaviors are possibly estimated through the cerebral cortex electroencephalogram with electric activity of cerebrums [1]. But for active and sensitive animals, such as horses, it is rather difficult continuously to apply the electroencephalograms. Through the cerebral cortex electroencephalogram measurement for cattle the rest behaviors are closely related with the eyelid and eyeball movements, so the observing continuous eye movement of horses gives us the characteristics of their rest habit without giving them much stress.

II. MONITORING SYSTEM AND MATERIALS

A. The Mask

At first, the special mask (Fig. 1.) attached a miniature CCD camera to measure the eyeball and eyelid area continuously, was newly developed.

Characteristics of the mask are,

1. Whole weight is very light as c.a. 400 g (battery is 230 g). This gives less stress to horses for long time monitoring.
2. Usually horses have high temperature and are much sweating, so the mask haves several holes at the plastic transparent dome shown as Fig. 1, which holds CCD camera and is able to look outside clearly.

Fig. 1. Horse wears the special mask in a stable

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Abstract

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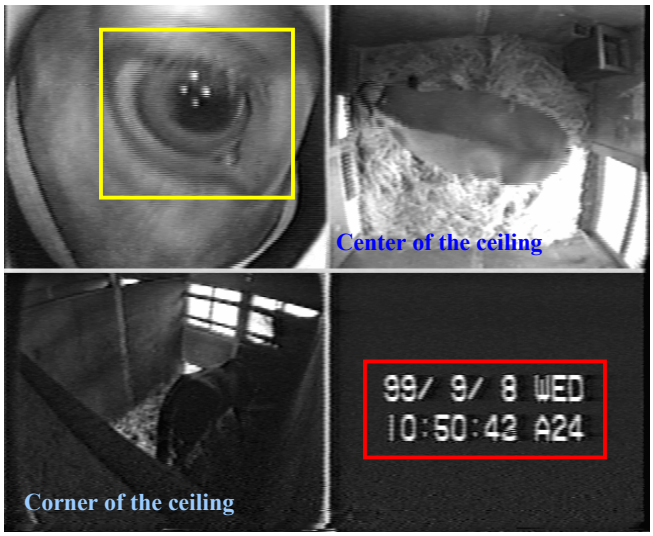

Fig. 2. A sample image captured by the image processing system.

3. Several LED (peak wavelength: 940 nm) are settled to illuminate the eyeball area for the 24 hours continuous measurements. The lighting influence seems to be negligible, because horses cannot recognize the light of this wavelength.

B. Measurements

Horses are usually very delicate, so the whole measurement was carried out in their stable, where they already used to. The observed eyeball and eyelid movements by CCD camera, was sent by telemetry system and was stored with time-lapse video recorder in 1 / 12 times speed using 120 minutes VHS tapes. In the stable, two other CCD cameras were also settled at the ceiling to observe the whole behaviors of the horse. The one was set up at the center of the ceiling and was looking vertically, the other was settled at the corner of the stable. Through these two cameras the whole behavior of horses was observed continuously (Fig. 2.). Upper left of Fig. 2, the eyeball area taken by the miniature CCD camera on the mask is shown, and upper right and lower left, posture of horse in the stable are observed. The date and time are shown at the lower right of Fig. 2.

In this study, only the right eyeball was observed because eyeball and eyelid movement of the horse is not very different essentially at left or right. Consequently, the continuous observations of horse eyeball and eyelid movement were carried out in good conditions of less stress to them. The data were collected as the subjects with 7 examples for 4 horses (age: 1 to 10) as shown in Table. 1.

III. Analyses

A. The Analyses Procedure

The image storing and analysing system was built with a video player, a captureboard (GINGA REAL) and HALCON development environment for the image processing. The obtained time-lapse VHS tapes were played back with a video player, and images were digitized consecutively at the sampling rate of 6 fps (real interval is 1 frame / 2 sec) by a captureboard. The captured images are monochrome, 8 bit (gray level), 640 x 480 (resolution). The amount of images for an experiment is c.a. 43,000 / 24 hours.

B. Image Processing

The image processing was performed as the following two steps. First, to get the time and date informations of lower right on Fig. 2, the optical character recognition technology was applied. At the learning phase, template consisting of 20 features (height / width ratio, normed 2^{nd} relative geometric moments, horizontal and vertical projection of gray values, and etc.) was trained. The convergence was condition with the average confidence ≥ 0.74. At the recognition phase, the time and date strings in a image were identified through the obtained template. Some misrecognized time strings are corrected by refering the context of time string before and after.

Secondly, Program for estimating the eyeball area shown in upper left on Fig. 2. was developed [2, 3]. Each image was originally composed of two field images captured on different time, because the images were obtained from interlaced video. These two field images having the image property in different electrical position were stored as one frame image by digital format. This makes a blur in frame image, and every odd line is re-calculated and interpolated. Then, the eyeball region were selected, stepwisely enhanced with the linerised histogram, smoothed linerly with the gray values averaging, and filled up small holes if less than 10,000 pixels by erosion and dilation procedures. The segmentation of eyeball region was finally carried out and was measured each value.

C. Smoothing Noise

Some eyeball images were unable to obtain the segmented area on account of the quality of VHS tapes. The value of eyeball area comparing with the before and after values were smoothed by a median filter (order 31) to eliminate the noises.

Table. 1. The measurement environment for each example

No.	Name	Age	Sex	Measurement condition	Start time	End time
1	Christifany	3	Male	Graze in the previous day	99/09/21 15:58	99/09/22 16:37
2	Christifany	3	Male	In a stable from the previous day, Light up all night	99/09/07 16:13	99/09/08 14:07
3	Whitesound	3	Male	Ride in the previous day, Graze in the morning	99/11/09 14:47	99/11/10 15:05
4	Rainboweye	4	Female	Die battery in midnight	00/08/08 14:33	00/08/09 03:20
5	Rainboweye	4	Female	Graze in the previous day	00/08/14 13:59	00/08/15 13:55
6	Rainboweye	4	Female	Graze in the previous day	00/08/17 13:48	00/08/18 14:06
7	Friends	10	Male	Graze in the previous day	00/08/29 16:09	00/08/30 16:56

"Order 31" means the median of the time series of before 15 frames (30 sec) and after 15 frames (30 sec) of eyeball area, because the captured sampling rate was 1 frame / 2 sec in real interval. Followingly, the spectrum analyses were carried out.

IV. Results

7 subjects were analyzed. Two of them (No. 1. and No. 2.) are listed in Fig. 3 to Fig. 8.

A. The Temporal Trend

The fluctuating status of eyeball area for about 24 hours was showed Fig. 3, and Fig. 4. Legend "Measurement" indicates estimated eyeball area based on the continuous time. Legend "Smoothed" indicates filtered "Measurement". Nemoto et al. had already measured and reported that the fluctuating status of eyeball area gotten from continuous measurement for about 24 hours of the cerebral cortex electroencephalogram and eyeball open or close level of cattle can be estimated "fluctuating status of awaking level" [1]. The eyeball area near 7, 9, 13 and 15 o'clock (Fig. 3.) and near 18, 21, 23, 7 and 9 o'clock (Fig. 4.) is highly at "Smoothed". It can said that the awaking level of horse near these time is highly. The awaking level of horse near theses time is lowly because the eyeball area near 1 and 2 o'clock (Fig. 3.) and near 5, 10 and 12 o'clock (Fig. 4.) is lowly. The trend which sleeping and awaking is repeated about 1.5 ~ 2.0 hours cycle was confirmed. This trend is similar to other 5 examples. The sunset was 18:00 (No. 1.), 17:28 (No. 2.) and the sunrise was 5:17 (No. 1.), 5:28 (No. 2.). The awaking level is a peak at the sunset and it is increasing trend at the sunrise. This trend is similar to other 5 examples.

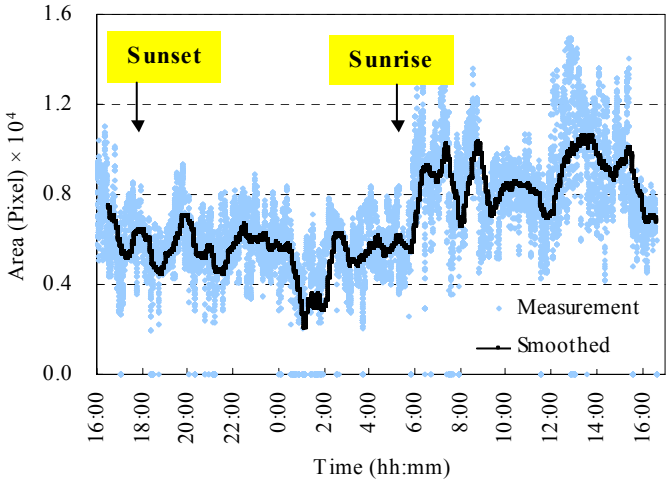

Fig. 3. The temporal trend of eyeball area (No. 1)

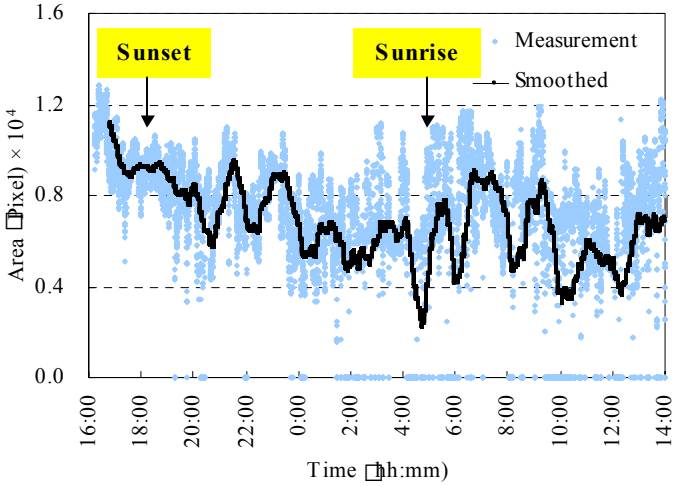

Fig. 4. The temporal trend of eyeball area (No. 2)

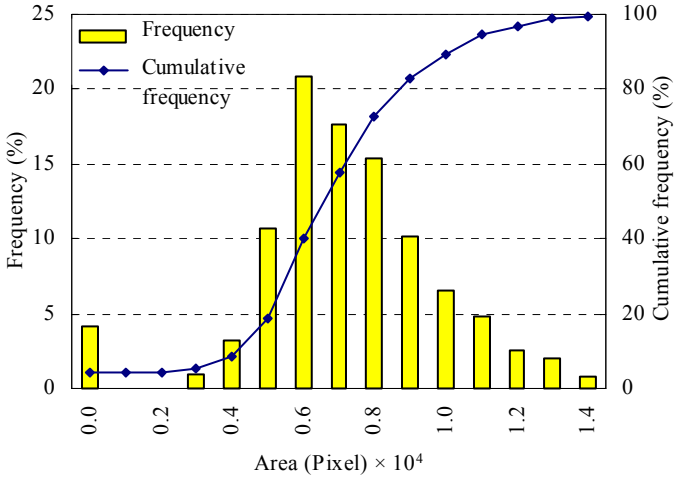

Fig. 5. The histogram of eyeball area (No. 1.)

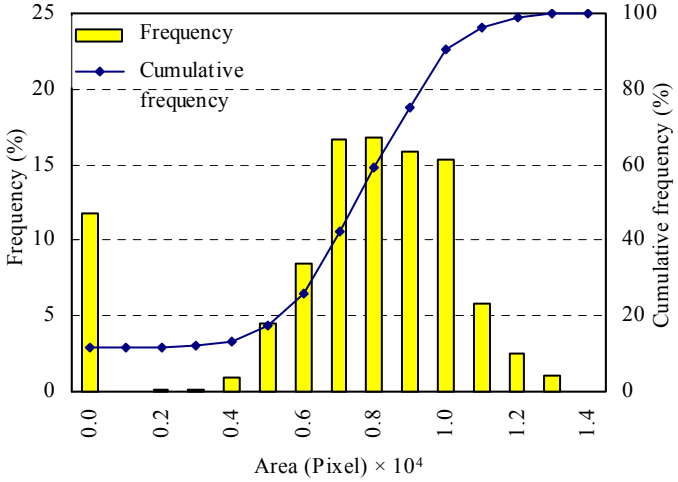

Fig. 6. The histogram of eyeball area (No. 2.)

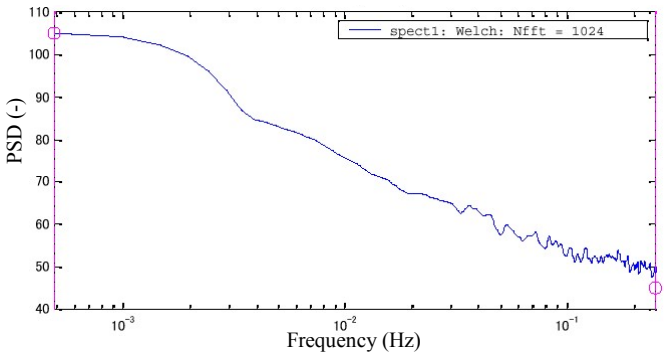

Fig. 7. The spectrum of eyeball area (No. 1.)

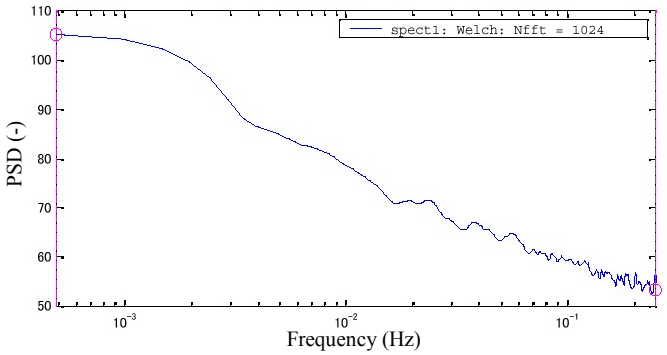

Fig. 8. The spectrum of eyeball area (No. 2.)

B. The Histogram and spectrum

The histograms of estimated eyeball area showed in Fig. 5, and Fig. 6. The fraction of eyeball area indicates an closed eye (their ratios are 4 % in Fig. 5, and 12 % in Fig. 6.) respectively. It was distributed 4 ~ 17 % in 5 of 7 examples and the increasing trend of cumulative frequency was similar in 4 examples. The eyeball area $\geq$ 1.1 x 10^4 pixel was about 11 % of all (Fig. 5, and 6.) and fully opened eye is about 2.6 hours / day.

The spectrum of eyeball area showed Fig. 7, and 8. The spectrum trend is similar to other 5 examples.

V. Discussion

The median filter was compared with order 5, 31, 101 and 1001 to research most effective order. The order 5 is not so different to compare with measured eyeball area. The order 101 and 1001 is different only 1.5 and 3.8 % compared with order 31. The order 31 was used as most effective median filter because the calculation time increases as an exponential function with increasing order.

Sampling rate was decided on 6 fps (real interval is 1 frame / 2 sec) but it may not exactly detect the movement of eyeball that blinking hardly. Sampling rate needs about 30 fps to obtain exact information of eyeball area [4]. If the continuous images for 24 hours are captured to hard disc at 30 fps, total images are 200,000 and 60.2 GB on size. The segmentation of eyeball region on No. 3 was difficult because the difference of gray values was little. The segmentation of a border of eyeball and eyelid was difficult on No. 4, 5 because the images hardly blurred to shine the eyeball directly. This problem will solve by shutting the curtains at a window of stable.

VI. Conclusion

The eyeball area estimating rest rhythm of horses was measured quantitatively. Based on the analysis, the following conclusions can be drawn.

1. A cycle of sleeping and awaking is confirmed to be about 1.5 ~ 2.0 hours
2. The horses do not rest at the sunset continuously and the intermittent fluctuating of awaking level can be seen the night
3. The awaking level is increasing trend at the sunrise and the rest term at daytime means that the horses are not active condition any time.

VII. Reference

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